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INFLUENCE OF MOMENTUM AND CHARGE CONSERVATION ON AZIMUTHALLY SENSITIVE CORRELATIONS

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Charge neutralisation procedure based on a Markov chain Monte Carlo algorithm is applied to a system of generated hadrons. The algorithm changes the charge of a randomly picked particle by shifting it within its isomultiplet. For baryons changes in both electric charge and baryon number are applied and the algorithm leads to charge and baryon number neutralisation. The procedure can thus be used to study the effects of the local charge and baryon number conservation. We attempt to study these together with the local momentum conservation and their effect on azimuthal correlator observable sensitive to local C and CP violation in quark-gluon plasma.

1 Motivation

Recently, much attention has been paid to the suggestion that local P and CP violation can take place in the hot and dense matter produced in heavy-ion collisions. In non-central collisions, this leads to charge separation, i.e. an asymmetry in the number of positive and negative particles emitted along the angular momentum vector of the collision, the so-called Chiral Magnetic Effect [2].

The charge separation is described phenomenologically by adding a sine term to the Fourier decomposition of the charged-particle azimuthal distribution [3]:

$$\frac{dN_\alpha}{d\Phi} = 1 + 2v_1 \cos(\Phi_\alpha - \Psi_{RP}) + 2v_2 \cos(2(\Phi_\alpha - \Psi_{RP})) + \dots + 2a_\alpha \sin(\Phi_\alpha - \Psi_{RP}) + \dots, \quad (1)$$

Φ_α , Ψ_{RP} are the azimuthal angles of the charged particle and the reaction plane, respectively (α, β standing for the charge of the particles)

v_1 , v_2 are coefficients linked to the directed and elliptic flows

a_α describes the charge separation relative to the reaction plane.

Since $\langle a_\alpha \rangle = \langle a_\beta \rangle = 0$, a different observable must be employed to study the effect, using the fact that $\langle a_\alpha a_\beta \rangle \neq 0$. The observable is the azimuthal correlator $\gamma_{\alpha\beta}$, defined as follows:

$$\gamma_{\alpha\beta} \equiv \langle \cos(\Phi_\alpha + \Phi_\beta - 2\Psi_{RP}) \rangle \quad (2)$$

$$= \langle \cos(\Phi_\alpha - \Psi_{RP}) \cos(\Phi_\beta - \Psi_{RP}) \rangle - \langle \sin(\Phi_\alpha - \Psi_{RP}) \sin(\Phi_\beta - \Psi_{RP}) \rangle \quad (3)$$

$$= \langle v_{1\alpha} v_{1\beta} \rangle - \langle a_\alpha a_\beta \rangle, \quad (4)$$

where Φ_α, Φ_β are the azimuthal angles of the two charged particles.

It was, however, observed that the correlator $\gamma_{\alpha\beta}$ may be sensitive to local conservation of momentum, transverse momentum and charge. These effects have been studied separately in various publications [4,5]. We attempt to study the momentum, charge and baryon number conservation and their joint effect on $\gamma_{\alpha\beta}$.

2 Our approach

The charge conservation is enforced on the system of generated hadrons by a charge neutralisation procedure based on a Markov chain Monte Carlo algorithm. The charge of a random meson is shifted within its isomultiplet. The process is illustrated in Figure 1 on the pion isotriplet. The direction of the alteration is determined by another random number.

For baryons, changes in both electric charge and baryon number are applied. We show an example of the procedure in Figure 2 on the nucleon isodoublet. Either a nucleon changes into antinucleon or the proton (antiproton) and neutron (antineutron) are interchanged. The nature of the alteration is again determined by generating a random number.

The momentum conservation is ensured by generating the particles with the Lorentz Invariant Phase Space generator REGGAE [1]. Since the azimuthal correlator is non-zero only in non-central collisions with elliptic flow being non-zero, we simulate the elliptic flow using two samples of hadrons moving away from each other in x-direction, as is indicated in Figure 3.

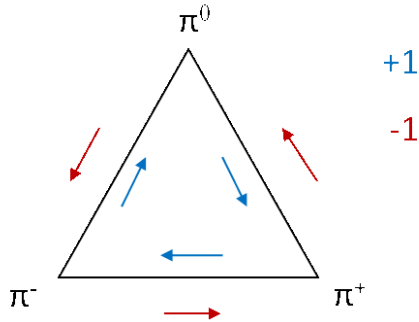


Figure 1. Charge neutralisation algorithm for pions.

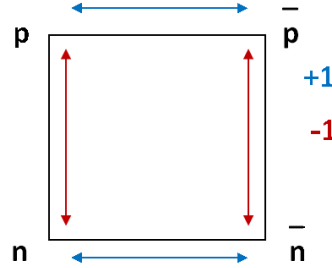


Figure 2. Charge and baryon number neutralisation algorithm for nucleons.

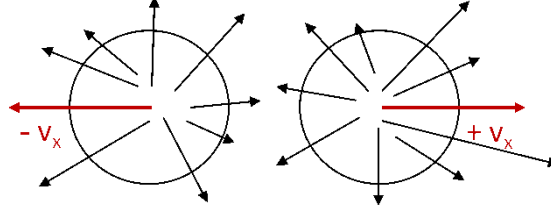
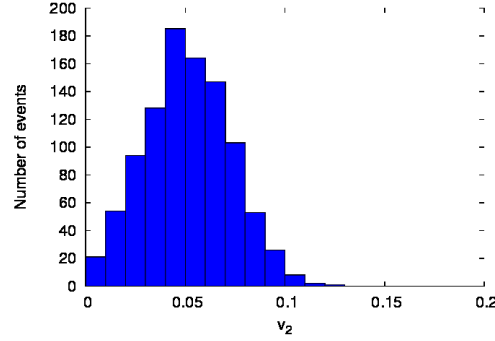


Figure 3. Toy model simulation of the elliptic flow.

Figure 4. Histogram of the simulated integrated elliptic flow v_2 .

3 Results

The variable which we specifically modelled to obtain a system similar to a non-central heavy-ion collision is the elliptic flow v_2 . We adjusted the parameters of the simulation to find values of v_2 corresponding to experimental ones. The histogram of integrated v_2 is shown in Figure 4.

The multiplicity dependence of the azimuthal correlator γ is shown in Figure 5. The correlator was calculated for all pairs of charged particles, like-sign particles (positive and negative presented separately) and unlike-sign particles. The three types are shown in Figure 5. No significant difference was found between the values of the azimuthal correlator of like-sign and unlike-sign particle pairs. This induces that the contribution of joint momentum, electrical charge and baryon number conservation to the observable γ is independent of the combined charge of the hadron pair.

The observed signal from the toy model qualitatively agrees with the measured correlation of unlike-sign pairs [6]. We miss, however, completely the correlation

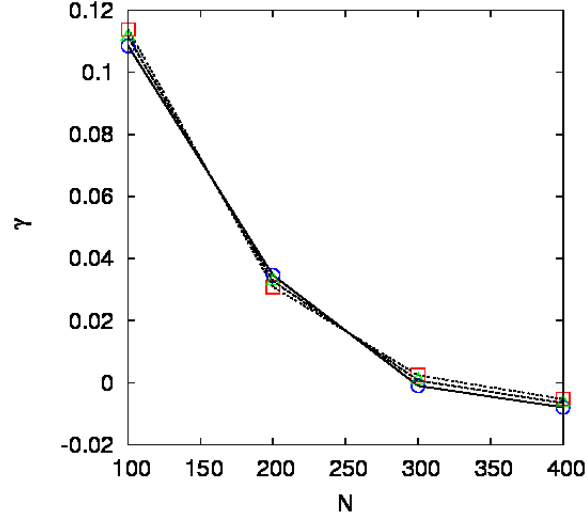


Figure 5. Multiplicity dependence of the azimuthal correlator γ , triangles and dashed line correspond to pairs of particles with opposite charge, circles and solid line correspond to negative particles, squares and dotted line correspond to positive particles.

of like-sign pairs. This may be due to non-inclusion of local charge conservation; charge was conserved only globally. We shall continue to investigate the topic.

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